BELL TELEPHONE LABORATORIES INCORPORATED BELL SYSTEM

Airborne Communication System: MARCOM RELAY

Report No. 3

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Third Quarterly Progress Report

December 15, 1962, to March 15, 1963

April 15, 1963

Contract No. DA-36-039-sc-89250

U. S. Army Electronics Research and Development Laboratory
Fort Monmouth, New Jersey
Department of the Army Project No. 3B55-04-001-01

Prepared by Bell Telephone Laboratories, Incorporated
On behalf of Western Electric Company, Incorporated
222 Broadway, New York 38, N. Y.

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Airborne Communication System

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Contract No. DA-36-039-sc-89250

Signal Corps Technical Requirement SCL-4313A

Department of the Army Project No. 3B55-04-001-01

The objective of this investigation is to gather and analyze information on air-to-air and ground-to-air microwave propagation and transmission. The findings will aid in predicting the capabilities of multichannel microwave communication systems using airborne radio relay stations and should provide information basic to the design of airborne systems.

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1. BACKGROUND AND PURPOSE

In January 1961, Bell Telephone Laboratories, Incorporated, on behalf of the Western Electric Company, Incorporated, prepared an unsolicited proposal for the Office of the Chief Signal Officer, Army Communication Systems Division, entitled "A Proposed Airborne Communication System for Survivable Communications." As a result of the interest stimulated by the proposal, the Signal Corps, Fort Monmouth, N. J., issued a request for a proposal to cover work consisting essentially of the program described in Phase 1 of the unsolicited proposal and governed by Technical Requirement SCL-4313 issued with the request.

In response to this request, the Laboratories, on behalf of the Western Electric Company, prepared a second proposal entitled "Airborne Communication Study," covering work to be accomplished in accordance with Technical Requirement SCL-4313, as amended. In June 1962 a contract was awarded by the United States Army Signal Supply Agency at Fort Monmouth, providing for an 18-month study based on the second proposal. Work under the contract is being performed by Bell Telephone Laboratories on behalf of the Western Electric Company.

The objectives of the program were to determine the capabilities and limitations of an airborne communication system and to establish a system engineering plan for its implementation within the continental United States. In the course of this study it was concluded that the existing information on radio propagation was not adequate either for system planning or for engineering a microwave airborne communication system. A propagation test program to measure microwave transmission between two aircraft and from a ground station to either aircraft was therefore included in the investigation. Leased aircraft were to be utilized.

In late 1962, the Director of Defense Research and Engineering (DDR&E) ordered a reorientation and redirection of the work under this program. Following this, the Defense Communications Agency/National Military Command System (DCA/NMCS) issued a Test Directive entitled "Air-to-Ground, Air-to-Air Propagation Test Program," which outlined a plan for the redirected project. In response to the Test Directive, Technical Requirement SCL-4313A, dated January 10, 1963, and covering the requirements of the Directive, was issued by the contracting agency. This document called for reduced emphasis on system planning and related studies and increased emphasis on propagation and transmission tests. In addition, it stated that aircraft and associated services will be provided by the government.

The main purpose of the reoriented program is to derive propagation information for predicting performance and capabilities of multichannel communication systems, using airborne radio relay stations operating at microwave frequencies.

Although the results of the reoriented study may lead ultimately to the development and design of operational systems, development and design are beyond its scope.

The reoriented study has been divided into the following two parts, which are discussed in detail in sections 4 and 5 of this report:

a. The Test Program has as its objective the collection of data on air-to-air and ground-to-air propagation. For reporting purposes, the Test Program has been subdivided into the following areas:
    1. Testing plans
    2. Data collection
    3. Data analysis
    4. Equipment procurement

b. Background Investigations will be carried out to gather and generate basic information that is needed for the over-all study. For reporting purposes, these investigations have been separated into the following study areas:
    1. Transmission
    2. Branching techniques
    3. Radio equipment
    4. Antennas
    5. Aircraft replacement
    6. Frequency allocations

2. ABSTRACT

2.1 GENERAL

Much of the project activity during the early portion of this reporting period was concerned with reviewing and modifying plans for future work on the redirected project. Several conferences were held with representatives of the United States Army Electronics Research and Development Laboratory (USAELRDL) and DCA/NMCS to discuss the proposed redirection and to draft a formal test plan. (Details of these conferences will be found in Section 3 of this report.) In addition, a work statement, cost estimates, and a program outline and periodic program plan for performing the work under SCL-4313A are in preparation.

2.2 TEST PROGRAM

The Test Program has been revised to conform to the requirements of the redirected project. Sixty-channel transmission will be tested rather than 24-channel transmission as planned under the original program. The transmission evaluation will be based on simulation rather than on use of actual multiplex equipment. As before, data will be collected to determine the effects of a number of environmental conditions on received signal strength and to evaluate their role in causing distortion in multichannel transmission. The merits of space and frequency diversity will be evaluated, and data will be gathered on operation of the antenna tracking systems.

Earlier plans for data processing and analysis are being revised to conform with the revised Test Program. Present plans call for a preliminary screening of data on site with subsequent detailed processing at the Whippany Laboratory. To as great an extent as possible, reduction and analysis will be done by electronic computer.

Equipment procurement in all areas is well under way. Under the revised program, the Air Force will supply the aircraft, modify them, and fly them during the tests.

The 60-channel microwave equipment has been ordered, and antennas and feed horns have been built and are being tested. During the quarter, one automatic signal tracking system was completed and shipped to Whippany; the other will be shipped shortly.

The ground station will be housed in a 40- by 8-foot trailer. The interior plan for the trailer has been completed. Its facilities will include an antenna mount that will allow the antenna to be stowed when not in use or when the trailer is moved from one location to another.

2.3 BACKGROUND INVESTIGATIONS

2.3.1 Transmission

The transmission objectives that were developed before the project was reoriented are being updated to cover transmission of 60 channels. These objectives will include such parameters as frequency and delay distortion, noise objectives, and stability.

2.3.2 Branching Techniques

Methods of filtering a 12-channel group from a 60-channel supergroup in the airborne platform are being studied, along with methods of branching transmission of a 12-channel group. No major technical difficulties are anticipated in the branching.

The study of airborne switching has been terminated except as it bears on the branching of 12-channel groups. The concluding study appears in this report as Appendix A.

2.3.3 Radio Equipment

The new requirement for 60 channels, requiring a base bandwidth of some 250 kc, has necessitated a restudy of the electrical characteristics of the radio equipment. This work is being initiated.

2.3.4 Antennas

The continuing review of antenna requirements for multidirectional microwave airborne communications has led to a general definition of the problems involved. Work is now being initiated to determine the best solution.

2.3.5 Aircraft Replacement

The various parameters and system configurations required for the study of initiation of service and aircraft replacement have been formulated on the basis of the system work performed prior to the redirection of the project. Several specific procedures are under study for replacing aircraft with minimum interruption in communication service.

2.3.6 Frequency Allocations

The scope of the radio frequency allocation work is basically unchanged by the redirection of the program. Work to date is reviewed here. Frequency plans for several probable system arrangements are now being studied.

3. PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

Conference Date: January 8, 1963

Place: Bell Telephone Laboratories, Whippany, N. J.

Organizations Represented: BTL, USAELRDL, WECo.

Subject: Reorientation of Project

Resume: The conferees discussed the preliminary unofficial draft of the revised Technical Requirement SCL-4313A for the Airborne Communication System project, the USAELRDL Test Plan, and schedules for the reoriented program.

Conference Date: January 14, 1963

Place: Bell Telephone Laboratories, Whippany, N. J.

Organizations Represented: BTL, DCA/NMCS, USAELRDL, WECo.

Subject: Test Schedule for Reoriented Project

Resume: The representative from DCA/NMCS emphasized that this agency would need meaningful test results by November 1, 1963. Obstacles to this objective are (1) modification of aircraft, (2) procurement of microwave radio equipment, and (3) procurement of measuring equipment. These obstacles were discussed at length, together with means for expediting the work. It was agreed to call a meeting of interested agencies to draft a formal Test Plan for the revised program.

Conference Date: January 22, 1963

Place: USAELRDL (Evans Area), Fort Monmouth, N. J.

Organizations Represented: BTL, USAELRDL

Subject: Test Program

Resume: The conferees discussed meteorological conditions affecting microwave propagation. The possibility of obtaining support from the meteorological division of USAELRDL was also explored. It was learned that the recent transfer of the meteorological support mission to the Army's Fort Huachuca in Arizona would preclude obtaining such support.

Conference Date: January 25, 1963

Place: Bell Telephone Laboratories, Whippany, N. J.

Organizations Represented: BTL, USAELRDL, WECo.

Subject: Test Planning Meeting of January 29 to 31, 1963

Resume: The Test Plan Outline prepared by USAELRDL was discussed, as well as test schedules and procurement of microwave radio equipment. It was found that production of the microwave equipment would be delayed until a new contract could be drawn up between BTL and the Collins Radio Company of Dallas, Texas.

Conference Date: January 29-31, 1963

Place: Bell Telephone Laboratories, Whippany, N. J.

Organizations Represented: Aeronautical Systems Division (ASD) of the United States Air Force, Army Materiel Command, BTL, DCA/NMCS, the Federal Aviation Agency, Headquarters USAF, USAELRDL, WECo.

Subject: Test Plan for the Reoriented Airborne Communication System

Resume: A Test Plan was drafted to define a test program with the purpose of providing information on air-to-air and ground-to-air propagation at microwave frequencies. Schedules included in the draft of the Test Plan are tentative and are contingent upon the project's being assigned sufficiently high military priority ratings. Another condition is that a letter contract for microwave radio equipment be submitted to the Collins Radio Company by February 15, 1963, with a DX procurement priority.

Conference Date: February 7 and 8, 1963

Place: Bell Telephone Laboratories, Whippany, N. J.

Organizations Represented: ASD, BTL

Subject: Flight Test Areas

Resume: The flight test areas originally proposed for the Test Program contained many restricted areas which severely limited flight planning. During this conference, revised test areas were selected which avoided restricted areas as much as possible. The revised test areas are also more convenient to the Wright-Patterson Air Force Base, Dayton, Ohio, where the aircraft will be based.

Conference Date: March 5 and 6, 1963

Place: Wright-Patterson Air Force Base, Dayton, Ohio

Organizations Represented: ASD, BTL, the Air Force Systems Command, USAELRDL

Subject: Test Plan

Resume: The Test Plan drafted at the conference of January 29-31, 1963, was reviewed. Revisions were made to reflect the latest schedules and plans, as agreed to by the conferees.

Conference Date: March 7, 1963

Place: Wright-Patterson Air Force Base, Dayton, Ohio

Organizations Represented: BTL, General Electric Co., USAF

Subject: Problems Concerned with Test Program

Resume: There was a discussion of specific aircraft problems, such as location of radomes, rack equipment installations, and power supply.

4. TEST PROGRAM

4. TEST PROGRAM

The First Quarterly Progress Report (S), dated October 15, 1962, discussed the need for propagation and transmission testing and described in detail preliminary plans for the Test Program. Since then, during the course of the study, there have been a number of changes in those plans, particularly in the data collection area.

The revised plans served as the basis for a formal Test Plan, which was prepared jointly by the participating organizations (see Section 3, conference of January 29-31, 1963). The official plan, titled "Test Plan for National Military Command System, Air-to-Ground/Air-to-Air Propagation Test Program," was issued by USAELRDL on March 15, 1963. A discussion of present test plans is included here to give a complete picture of the program as it now stands.

The purpose of the Test Program is to gather basic data on air-to-air and ground-to-air propagation in the 4400- to 5000-mc frequency band. Data will be derived to predict the performance and capability of 60-channel transmission instead of 24-channel transmission as planned under the original program. No tests will be conducted in which a signal is transmitted from the ground station to an aircraft and then relayed to a second aircraft.

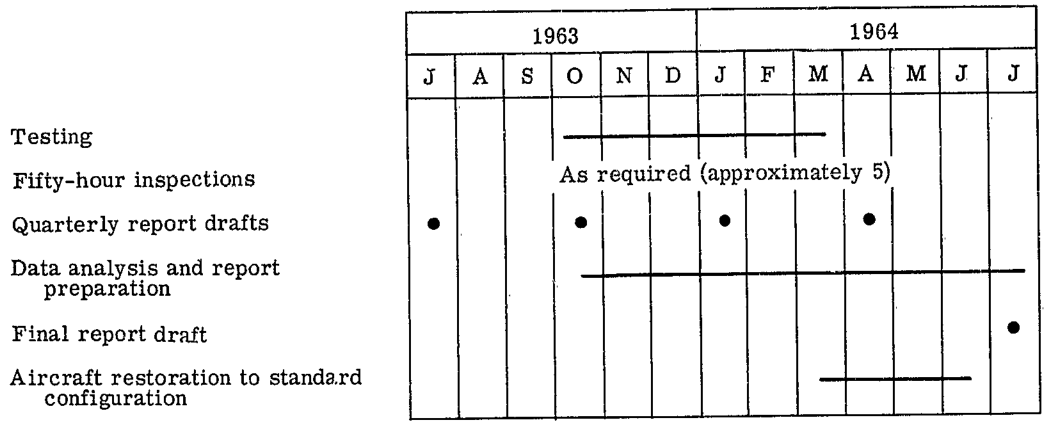
Specifically, data will be collected to evaluate the following factors:

a. The effects of aircraft separation, terrain clearance, topography, time of day, weather, and climate on
    1. Received signal strength
    2. Distortions in multichannel transmission, including the effects on tone stability, intermodulation distortion, and data-carrying capability

b. The merits of frequency diversity and space diversity

c. Operation of the airborne antenna tracking system

Based on current schedules for equipment procurement and on the availability of aircraft, testing will begin in October 1963 and end in March 1964. Data analysis will begin in October as soon as preliminary findings are available. Analysis should be completed in time for a final report in July 1964. The tentative test schedule is shown in Figure 1.



Note: This schedule represents a change in the present contract schedule and requires a modification of Contract DA-36-039-sc-89250.

Figure 1. Test Schedule

4.1 TESTING PLANS

4.1.1 Test Configuration

As illustrated in Figure 2, two aircraft will participate in the air-to-air tests. Ground-to-air tests will be made from a movable ground station to one of the aircraft.

The ground station will be equipped with two microwave transmitters and antennas. It will also have one h-f transceiver and antenna system for voice communications and test control, and test equipment for recording data and for maintaining the ground equipment.

These facilities will be installed in a trailer van as described in paragraph 4.4.4. Power for the ground equipment will be obtained from engine-driven generators mounted on trailers. The ground station will be moved to a location near or within each test area and then operated as a fixed station. No tests will be made while the ground station is in motion.

The aircraft selected for the test program are Lockheed Constellations, C-121. The microwave equipment installed in each aircraft will include two transmitters, four receivers, and two antenna mounts each equipped with two horn radiators. One microwave antenna system will be mounted on the topside of the

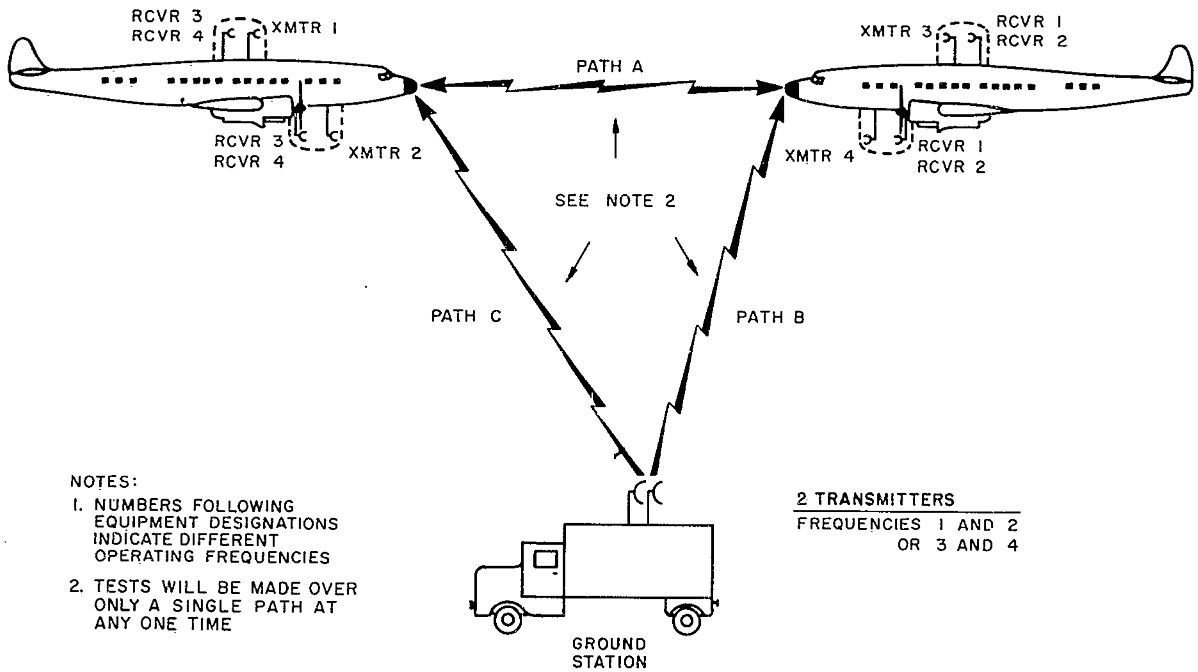


Figure 2. Test Configuration

aircraft, the other on the under side. Each aircraft will have two h-f transceivers, one for navigation and the other for voice communications and test control. In addition, each aircraft will be equipped with test instruments for recording data and for calibrating and maintaining the electronic equipment.

In order to provide maximum flexibility, both aircraft will be equipped alike except for operating frequencies.

4.1.2 Flight Patterns

Three basic flight patterns will be used for the tests. Initially, for air-to-air tests, the aircraft will fly in straight-line paths toward or away from each other. In the case of ground-to-air tests, the direction of flight of the aircraft will be toward or away from the ground station. This will provide continuous information on variations in transmission path loss as the transmitting and receiving stations move closer together or farther apart.

These tests will establish the station separations that will be used for gathering the bulk of the basic propagation data. These data will be collected with the aircraft flying in parallel flight paths at the selected station separations.

Finally, the aircraft will fly random paths within assigned areas, the centers of which will again be at selected station separations. This may be similar to the way aircraft would fly in an operational system. It will provide information on aircraft shielding and antenna tracking.

The three kinds of flight patterns are summarized as follows for both air-to-air and ground-to-air tests.

a. Air-to-air transmission
   1. A straight-line path with aircraft flying toward or away from each other
   2. Parallel flight paths at several selected separations to just beyond line of sight
   3. Random paths with each aircraft remaining within an assigned area; for example, two circular areas 50 nautical miles in diameter with the centers of the areas at selected distances apart

b. Ground-to-air transmission
   1. Radial paths to and from a preassigned location
   2. Arcs of circles at several ranges to just beyond line of sight
   3. Random paths within assigned areas centered at selected distances from the ground station

4.1.3 Terrain

Transmission data will be collected over three different kinds of topography in the areas described below. Each test area will be approximately 100 nautical miles wide by 450 nautical miles long.

a. Water. The Gulf of Mexico, south from New Orleans, Louisiana

b. Flat terrain. The Mississippi River Basin from Cairo, Illinois, south to Alexandria, Louisiana

c. Mountains. The Great Smoky Mountains from Lexington, Virginia, southwest to Gadsden, Alabama; and the Smokies from Florence, South Carolina, northwest to Cincinnati, Ohio

These geographical areas are shown in Figure 3. Two areas are shown for the mountainous region since propagation data are needed on paths both parallel to the mountain ridges and at right angles to them.

In each test area, the ground station will be located where it can maintain microwave and high-frequency radio contact with the aircraft. In the choice of the ground station site, factors to be considered are space for parking the trailers, accessibility, availability of telephone facilities and logistic support, and freedom from radio interference.

4.1.4 Test Conditions

Tests will be made under several different conditions to investigate a number of variables. The following paragraphs describe current planning in this area.

a. Time of day. On ground microwave systems, path-loss measurements made during the day generally agree with the theoretical path loss. This is because the atmosphere is usually homogeneous during daylight hours. On the other hand, path losses during the evening and night hours are apt to be much higher than theoretical. Also, fading may be more rapid and severe.

   Therefore, some tests will be conducted during the day to establish reference levels. However, most of the tests will be scheduled during night hours. These should provide information on the fade margins an operational system will need to provide reliable communications around the clock.

b. Aircraft altitude. In order to limit the number of test variables, a single aircraft altitude will be used throughout the tests. The tests will be performed at a target altitude of 23,000 feet above mean sea level. This

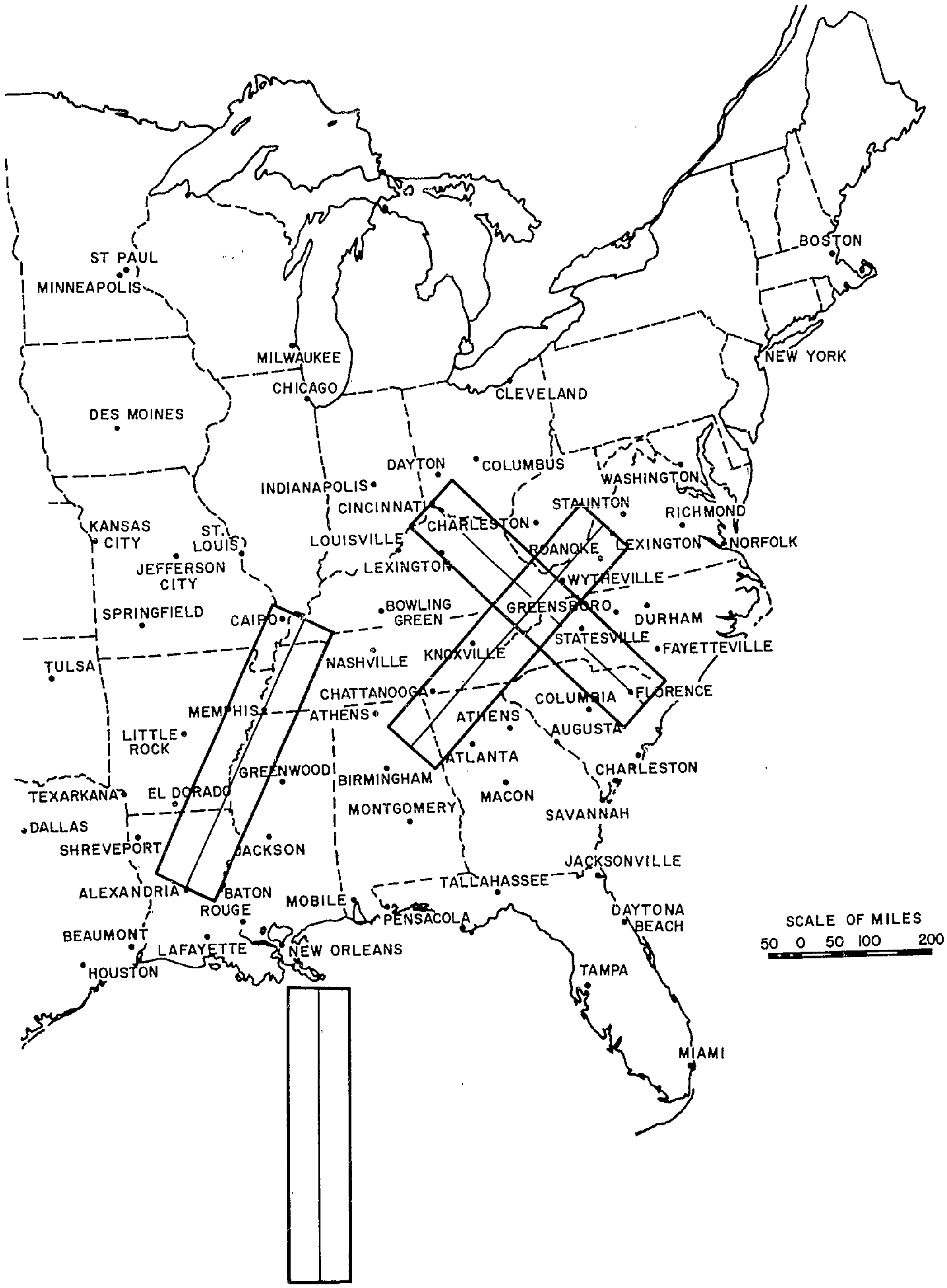


Figure 3. Test Areas

altitude permits two aircraft to be separated by about 310 nautical miles before the optical line-of-sight path between them just touches the smooth earth's surface. However, the earth's atmosphere causes microwave signals to be refracted toward the earth's surface. Hence, the radio waves follow a somewhat curved path rather than a straight line. When this curvature is taken into account, the aircraft can be separated by about 373 nautical miles before the signal path just touches the smooth earth.

c. Climate. Since it is impossible to control the weather prevailing during the scheduled five-month test period, the tests in the three areas will be scheduled to take advantage of their different climates. Test planners hope that transmission data can be gathered under atmospheric conditions varying from hot and moist to cold and dry, turbulent air to smooth air, and no rain to heavy rain. In any event, they plan to keep a complete record of atmospheric conditions throughout each test.

d. Operating frequencies. All tests will be conducted in the Government frequency band of 4400 to 5000 mc. The call sign is AA2XI and the following frequencies have been authorized for test use:

F1 — 4512 mc	F5 — 4487 mc
F2 — 4617 mc	F6 — 4592 mc
F3 — 4737 mc	F7 — 4762 mc
F4 — 4947 mc	F8 — 4972 mc

e. Frequency diversity. Data will be obtained to evaluate the merits of frequency diversity. As shown above, frequency assignments were requested in pairs to provide for frequency separations of 105 and 210 mc. These separations are approximately 2.3 per cent and 4.6 per cent, respectively, of the midoperating frequency. They should provide a good evaluation of the benefits frequency diversity may offer. Should the need arise, other frequency separations could be obtained by splitting the pairs.

f. Space diversity. Antennas will be mounted on the top and on the bottom of each aircraft. This arrangement provides some degree of space diversity. But more important, it adds insurance against loss of the communication circuit during aircraft turns when one set of antennas may be obscured by a portion of the aircraft. Data will be collected to evaluate the shielding effects of the aircraft frame.

4.1.5 Testing Schedule

As mentioned before, the tests will be conducted over a five-month period. A typical test schedule during a month might be as shown in Table 1.

Table 1

A TYPICAL TEST SCHEDULE FOR A MONTH

Type of Test	Number of Tests	On-Station Hours Per Test	Average On-Station Hours per Aircraft	Average Flying Hours per Aircraft*
Air-to-air				
Day	2	6	12	16
Night	5	6	30	40
Subtotal	7		42	56
Ground-to-air				
Day	2	6	6	8
Night	3	6	9	12
Subtotal	5		15	20
Total per month	12		57	76

*This includes time to and from station.

4.2 DATA COLLECTION

The data required to evaluate 60-channel group transmission will be based on simulation rather than on the use of actual multiplex equipment. Two basic types of propagation data will be collected:

a. Amplitude variations in the received radio-frequency signal power level as a function of time for various aircraft separations, terrain conditions, etc. These data will provide information on path loss and on the frequency and magnitude of fades.

b. Data relating to signal distortion and noise introduced into the receiver baseband signal by nonlinearity or other characteristics of the transmission media.

To obtain these data, provisions will be made for transmitting at least the following three kinds of signals:

a. An unmodulated carrier signal.

b. The carrier modulated with white noise over the entire 60-channel baseband and with two sine-wave signals located slightly beyond the upper and lower extremities of the baseband.

c. Signal (b) but with the white noise eliminated from a narrow slot approximately 3 kc wide located either near the upper or the lower end of the baseband. Figure 4 is a typical illustration of the relative positions of the components of the modulating signal.

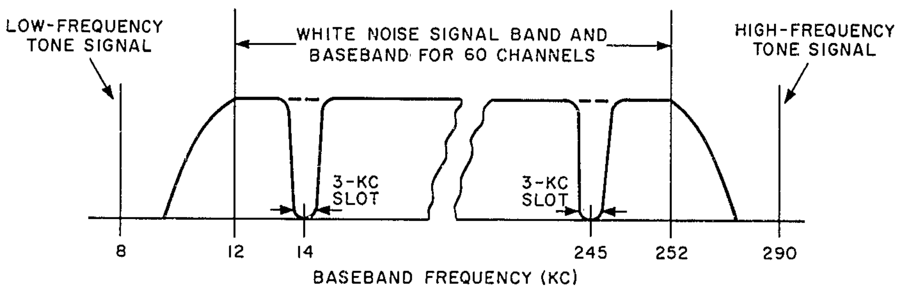


Figure 4. Test Signal for Modulating Carrier

During the test runs, the three kinds of signals will be transmitted successively for relatively short periods. Thus the three signals will be influenced by the same weather, terrain, equipment drift, and other slowly changing conditions that can be only partially controlled during the tests.

Specific data to be collected and the means and equipment that will be used to record those data are described below.

4.2.1 Radio-Frequency Signal Level

A voltage proportional to the received signal level will be continuously recorded on magnetic tape for each of the airborne microwave receivers. This voltage is a dc voltage designated the combiner control voltage (CCV). It varies from +18 volts, for a carrier level near the receiver noise threshold, to +33 volts for a carrier level 50 db above threshold.

The CCV from any one receiver in each aircraft may be selected by an operator for recording on one channel of a graphic recorder. In addition, two combined combiner control voltages — one for the two receivers connected to the top antenna of each aircraft and one for the two receivers connected to the bottom antenna — will be continuously recorded on the graphic recorders.

4.2.2 Received Baseband Signal Level

A signal from each receiver, proportional to the receiver output power measured across a 3-kc segment of the baseband, will be continuously recorded on magnetic tape. This will be accomplished by use of a Marconi OA-1249B or an equivalent white noise test set. The received 3-kc segment of the baseband will correspond to the 3-kc slot in the baseband transmitter modulating signal from which the white noise can be eliminated. Thus, for the three signals previously described, the noise receiver outputs recorded on magnetic tape will represent (1) the thermal noise level, (2) the total signal plus noise level, or (3) the thermal noise plus intermodulation noise level. It is also planned to collect similar data for a number of diversity combinations on a switched basis, by use of baseband combining techniques.

The noise outputs for one receiver or receiver combination in each aircraft will be selected manually for recording on one channel of the graphic recorder.

The received signal level for each of the two sine-wave signals mentioned in paragraph 4.2 will be recorded on magnetic tape. To reduce the number of magnetic tape recorder channels required, the two signal levels from one receiver or diversity combination of receivers will be selected for recording at a given time on a switched basis.

4.2.3 Antenna and Tracking System

The following data on antenna pointing and tracking will be recorded on a graphic recorder:

a. Aircraft
   1. Roll
   2. Pitch
   3. Compass heading

b. Master antenna
   1. Relative azimuth
   2. Relative elevation
   3. Antenna dither angle

c. Slave antenna
   1. Azimuth angle error
   2. Elevation angle error
   3. Antenna dither angle

4.2.4 Aircraft Environment and Position

The following indicators will be photographed or manually logged at regular intervals.

a. Electronic slave compass
b. Barometric altimeter
c. Air speed indicator
d. Outside air pressure indicator (same as item 4.2.5.1, a)
e. Outside air temperature indicator (same as item 4.2.5.1, b)
f. Standard eight-day aircraft clock
g. Digital clock
h. Range-to-beacon indicator
i. Angle-to-beacon indicator
j. Radar altimeter
k. Weather radar scope

4.2.5 Atmosphere

The atmospheric data in the following paragraphs are needed to describe completely the condition of the transmission medium both near the terminals of the test path and in the midpath region. All data must be keyed to time, location, and altitude of observation.

4.2.5.1 Data at Each Aircraft and at the Ground Station

a. Air pressure (accuracy: 1 millibar)
b. Air temperature (accuracy: 1 degree Kelvin)
c. Water vapor pressure (accuracy: 0.5 millibar)
d. Wind direction (accuracy: 16 points compass)
e. Wind speed (accuracy: 10 knots)

Items a, b, and c should be recorded in the air at 3-minute intervals and more frequently whenever significant changes are observed by the flight crew. On the ground, the data should be recorded continuously on a slow-speed graphic recorder or manually logged at 15-minute intervals or more frequently whenever significant changes occur.

Items d and e should be logged by the flight crew at each flight pattern check point and also between check points whenever significant changes are observed. At the ground station, the data should be recorded continuously on a slow-speed graphic recorder or manually logged at 15-minute intervals or more frequently whenever significant changes occur.

4.2.5.2 Data Along the Propagation Path. The following data are needed on atmospheric conditions present along the propagation path, particularly over the middle third of the test area. The measurements should encompass an air volume roughly 100 by 150 nautical miles by 15,000 feet.

a. Air pressure (accuracy: 1 millibar)
b. Air temperature (accuracy: 1 degree Kelvin)
c. Water vapor pressure (accuracy: 0.5 millibar)
d. Wind direction (accuracy: 16 points compass)
e. Wind speed (accuracy: 10 knots)

These measurements should be obtained by suitably equipped aircraft making vertical and horizontal soundings during each test period.

If such aircraft cannot be made available, the required data should be derived from weather radar observations and radiosonde measurements. The total number of stations required, the frequency of measurement, and the balloon ascension rate would depend on the general atmospheric disturbances common to the test area. For example, in an area having many local disturbances of short duration, small volume, or rapid motion, frequent and rather dense soundings would be needed. In an area characterized by a quiet homogeneous atmosphere, infrequent and widely spaced soundings would be acceptable. In any case, a minimum of three radiosonde facilities would be needed to provide valid data.

Irrespective of how the atmospheric data are obtained, they should be supplemented by weather information from the United States Weather Bureau and the Air Force Weather Service and by cloud cover information.

4.2.6 Miscellaneous

The additional items listed below will be recorded by various means:

a. Voice recording of communications on hf radio link
b. Microwave transmitters
   1. Power output
   2. Operating frequency
   3. FM deviation
   4. VSWR (meter reading on transmitter)

c. Microwave receivers
   1. Crystal mixer currents
   2. Operating frequency
   3. Calibration - power input versus CCV output

4.3 DATA ANALYSIS

Earlier plans for data processing and analysis are being revised to conform with the requirements of the redirected Test Program. Current plans call for the following general procedures for data handling and analysis. After each test run, data from various sources will be assembled at the aircrafts' home base and at the ground station. The information will be quickly examined to determine its validity and to permit on-the-spot comments to be entered when and where necessary. It will then be forwarded to the Whippany Laboratory for reduction and analysis.

At Whippany, graphic data will be checked and cross referenced while the magnetic tape and microfilm are processed. Through examination of a graphic reproduction of the magnetic tape, photographs, and flight logs, a qualitative summary of each test run will be made.

Information from this qualitative analysis will be fed back to test personnel to help them in planning test revisions, instrument changes, etc. This procedure will also provide verification of test results and aid in the selection of data for quantitative analysis. Appropriate portions of the magnetic tape, flight logs, and photographs will then be reduced to numerical form for the detailed computations required to complete the quantitative analysis of data.

Quantitative processing will be largely a computer operation, which will produce measures of feasibility in appropriate form (graphs, tables, etc.). It is tentatively planned to have graphs prepared directly by machine. Results of this analysis will also be forwarded to test planners.

Plans for data collection and analysis are under continuing study. More detailed procedures should be completed by the end of the next quarter.

4.4 EQUIPMENT PROCUREMENT

4.4.1 Aircraft

Under the revised program, the Air Force will supply the two aircraft for the Test Program. They will modify the planes to carry test equipment and will fly and maintain them throughout the testing period.

Figure 5 shows the present aircraft modification schedule. Work planned through March 15, 1963, has been completed as scheduled.

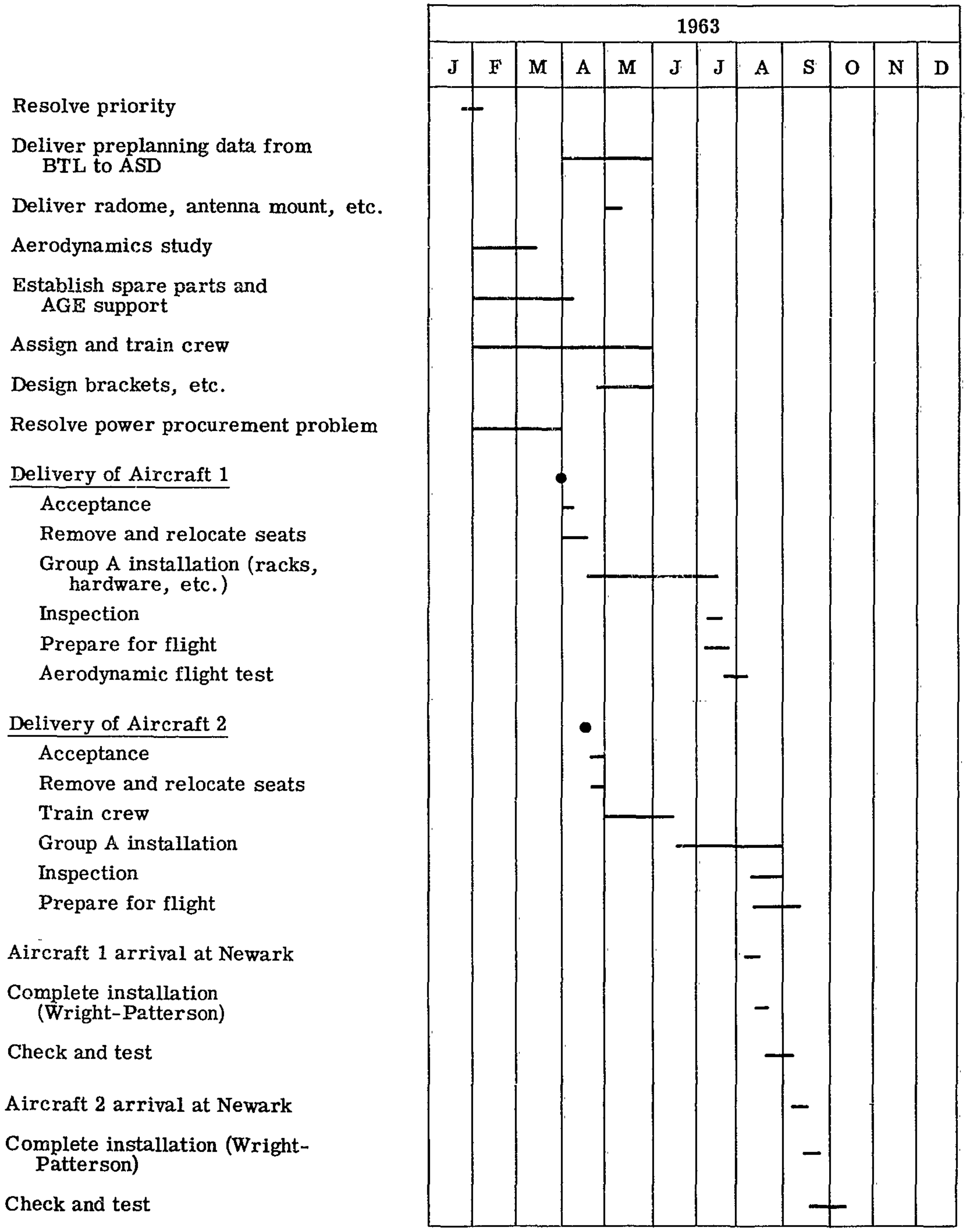


Figure 5. Aircraft Modification Schedule

4.4.2 Microwave Equipment

The microwave equipment discussed in the first two Quarterly Progress Reports, dated October 15, 1962, and January 15, 1963, was 24-channel equipment, which satisfied requirements for the original program. The revised Signal Corps Technical Requirement specifies 60-channel equipment for the Test Program. The 60-channel system uses most of the basic units of the 24-channel system but requires development of wider-band intermediate-frequency amplifier and discriminator units.

The equipment currently on order includes six 1-kilowatt FM transmitters, eight receivers, and associated equipment. The present schedule for manufacture and delivery of this equipment is shown in Figure 6. As scheduled, the Laboratories, with approval of the Contracting Officer, placed a letter contract with the supplier on February 15 for the 60-channel equipment. The supplier did not receive a DX priority on February 15, 1963. Therefore, the delivery date of all microwave equipment will be two weeks later than originally scheduled. Equipment for the first aircraft and the ground station is scheduled for delivery at Dallas, Texas, on May 31, 1963. Equipment for the second aircraft is scheduled for delivery on June 30, 1963.

4.4.3 Antennas and Tracking System

The microwave antennas and their associated pointing and tracking systems were described in detail in the Second Quarterly Progress Report, dated January 15, 1963. The current status of this equipment is discussed below.

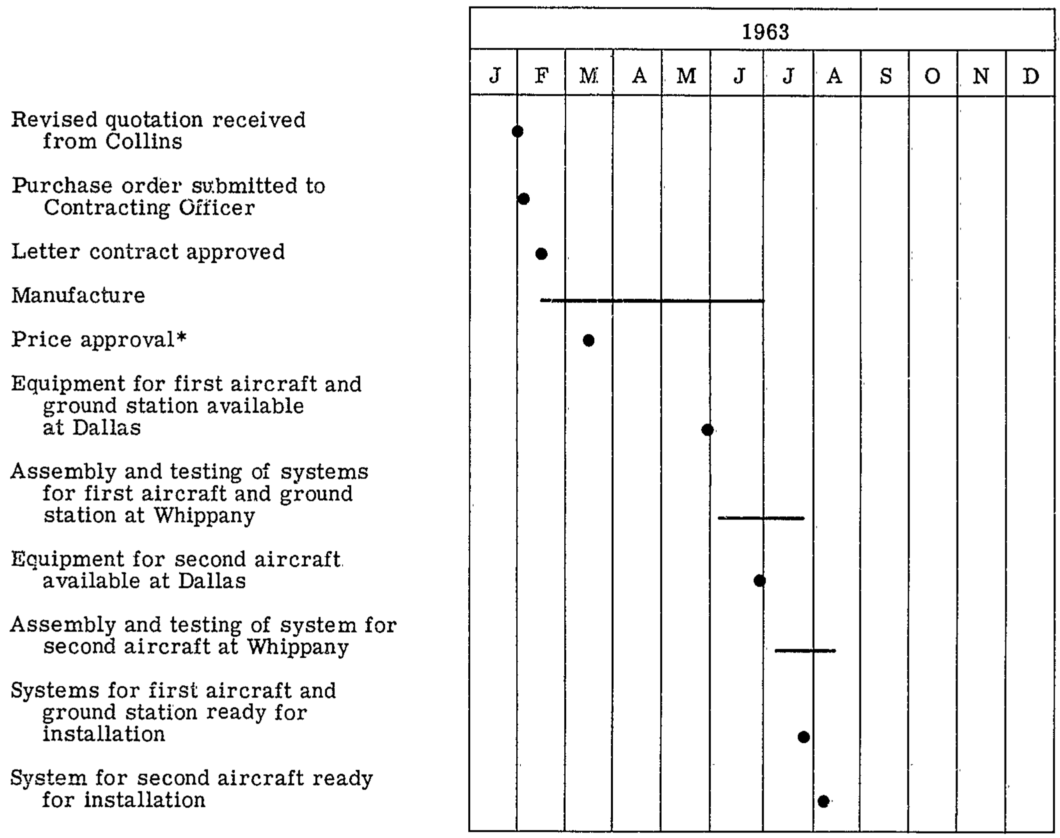
4.4.3.1 Microwave Antennas and Feed Horns. Production of the antennas and feed horns for the tests was completed this quarter. The electrical characteristics of one antenna were measured and found to be within design specifications.

Tests were also made with two antennas mounted side by side inside a radome, as they will be in an actual aircraft installation. The presence of the radome caused the following three effects:

a. The shape of the pattern changed slightly but, for all practical purposes, remained within specification limits.

b. The path loss between the test transmitter and receiver increased approximately 2 db.

c. The cross-coupling loss between the adjacent antennas decreased from approximately 71 db to 43 db, a change of 28 db. This amount of cross coupling is not expected to adversely affect the transmission test results.



*The price is under negotiation. The negotiations will not influence the equipment schedule.

Figure 6. Microwave Radio Equipment Schedule

4.4.3.2 Antenna Assemblies and Control Units. Fabrication of one slave antenna has been completed except for wiring and for the speed-reducer drive for the receiving antenna sector-scan mechanism. The scheduled delivery date for the speed reducer is April 1, 1963. This delivery date will not interfere with the start of antenna system testing, which is presently planned for March 22, 1963. Fabrication of the other antenna assemblies, including the various control and power supply units, is well under way.

The estimated dates for delivery of completely tested antenna systems are

Aircraft installation 1	June 1, 1963
Aircraft installation 2	June 7, 1963
Ground installation	May 13, 1963

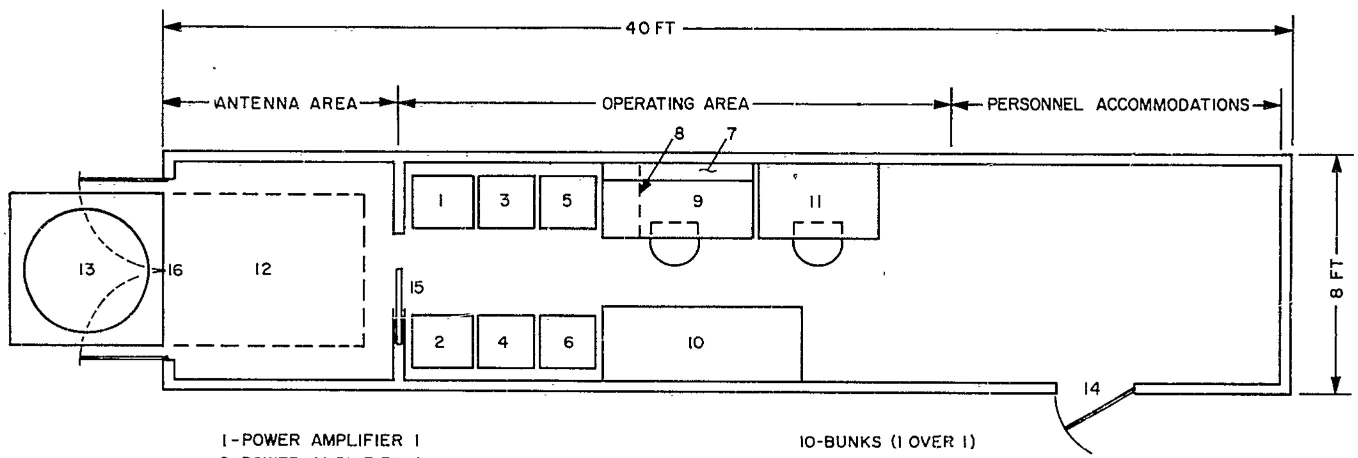
4.4.3.3 Automatic Signal Tracking System. The first system was completed during this quarter and shipped to Whippany on March 12, 1963. Integration testing of this unit with the antenna control and stabilization system will begin about March 22, 1963. The second tracking system is undergoing final testing and is scheduled for completion by March 20, 1963.

4.4.3.4 Problem Areas. The following items already have caused some delay, which is reflected in the schedule in paragraph 4.4.3.2. If current delivery dates are not met, further delays may result.

a. Dual channel rotary waveguide joint. The manufacturer is having difficulty meeting the electrical specifications for the rotary joint. In particular, the VSWR of the inner rotary joint is outside limits at the high and low ends of the frequency band. The outer joint is within specification limits. A progress report from the manufacturer is expected on March 22, 1963. The supplier also deviated from the mechanical specifications but this problem was taken care of through a modification of the antennas.

b. Slip rings and wipers. The supplier is experiencing manufacturing difficulties in providing acceptable rings. Faulty rings are being returned. This has delayed assembly of the antenna pedestals.

c. Speed-reducer drive and antenna heading indicator. Design information for these items was not fully converted to mechanical drawings until February 1, 1963. Therefore, quotations for all components were not received until March 8, 1963. The earliest estimated delivery date for the components is April 1, 1963. However, these items will not affect the delivery schedule in paragraph 4.4.3.2.



1-POWER AMPLIFIER 1
2-POWER AMPLIFIER 2
3-EXCITER 1
4-EXCITER 2
5-SPARE EQUIP RACK
6-SCOPE AND RECORDER
7-SHELF FOR HF GEAR
8-FILING CABINET
9-PLOTTING BOARD
10-BUNKS (1 OVER 1)
11-WORK TABLE
12-ANTENNA, STOWED POSITION
13-ANTENNA, OPERATING POSITION
14-ENTRANCE
15-SLIDING DOOR, ACCESS TO ANTENNA AND EMERGENCY EXIT
16-ANTENNA COMPARTMENT DOORS AND EMERGENCY EXIT

Figure 7. Preliminary Layout of Ground Equipment

d. Antenna mounting saddles. The upper and lower antenna mounting saddles cannot be fabricated until the contours of the specific aircraft to be used on the project can be measured.

4.4.4 Ground Station

The ground station will be housed in a 40- by 8-foot trailer, reinforced to sustain the added weight of the equipment to be installed.

As illustrated in Figure 7, the forward section of the trailer will be partitioned to house the antenna. This unit is designed so that it can be stowed when not in use or when the trailer is moved from one location to another.

Next to the antenna are two power amplifiers and their associated exciters. The trailer will also house three racks containing test equipment and the plotting board or test controller's desk. The h-f communications equipment will be located at this station. Two bunks will be installed, one above the other, behind the test controller's desk, to accommodate two operators during extensive or delayed tests. At the far end of the trailer will be a heating and air conditioning unit and an area for personnel facilities.

The test equipment racks will be built and tested at the Whippany Laboratory. The hardware required for mounting the antenna will be fabricated locally and assembled at Whippany. Current plans call for the trailer to be ready for installation of microwave equipment by May 30, 1963.

4.4.5 Test Equipment

The schedule for test equipment procurement is shown in Figure 8. A definitive list of test equipment was compiled on March 1, 1963, and quotations on most of the items have been received. Purchase orders are currently being prepared for this equipment.

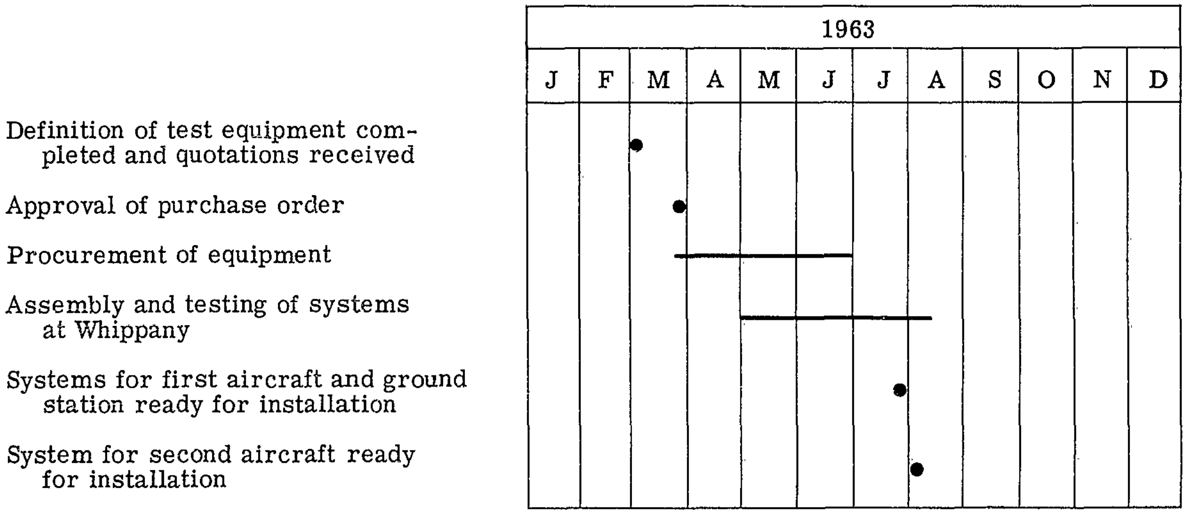


Figure 8. Test Equipment Schedule

5. BACKGROUND INVESTIGATIONS

5. BACKGROUND INVESTIGATIONS

As mentioned in Section 1, most of the task studies which formed part of the original contract have been terminated. Those that remain will be discussed in this section.

5.1 TRANSMISSION

The Signal Corps Technical Requirement SCL-4313A, dated January 10, 1963, states,

> The contractor shall investigate the performance and transmission capabilities of airborne communication systems. Specifically, the ability of transmitting 60-channel FDM groups between airborne platforms and between the platforms and ground stations. As part of this study, the contractor shall establish system design objectives which must be met from the standpoints of noise, intermodulation, distortion, echo, and internal and external interference specifically as affecting the quality of speech, teletype, facsimile, or data.

During the period covered by the present report, work has been started to determine the capability of an airborne microwave system to transmit 60 channels instead of the previously contemplated 16 or 24 channels. The transmission objectives which had been previously developed and which were summarized in the First Quarterly Progress Report, dated October 15, 1962, will be updated in the next Report. This summary will include such parameters as frequency and delay distortion, noise objectives, and stability, among others. The new data will result from a review of the electrical parameters involved in work that was undertaken on another contract for a system carrying similar signals in nominal 4-kc channels.

5.2 BRANCHING TECHNIQUES

The new specification states,

> The contractor shall investigate and recommend methods of filtering a 12-channel group from a 60-channel supergroup in the airborne platform and branching transmission of a 12-channel group.

There is no reason to believe that the filtering of a 12-channel group from a 60-channel supergroup will present any major technical difficulties. However, a study will be made to determine the method and the kind of equipment that will be recommended to accomplish this purpose.

Although airborne switching is no longer one of the task studies, the matter of switching (in the sense used in these studies) is related to the subject of branching. A memorandum has been prepared which supplements the discussion of switching given in Appendix E of the Second Quarterly Progress Report, dated January 15, 1963. This memorandum is included in the present report as Appendix A. It is concluded, with certain qualifications, that patching of individual channels in the airborne relays during flight is not worthwhile for the following reasons: (1) the gain in channel efficiency would be relatively small (the same is probably true of channel groups); (2) specially trained personnel not otherwise needed would be required in the airborne relays; (3) it would create the possibility of errors resulting in opening up or superposing busy channels; and (4) signalling and supervision would present problems. Further study of airborne switching is not contemplated, except as it bears on the branching of 12-channel groups.

5.3 RADIO EQUIPMENT

The new specification further states,

> The contractor shall determine requirements for the radio and associated equipments for air-to-air and air-to-ground transmission in the microwave multichannel airborne communications system. As part of this study, the contractor shall investigate suitable modulation techniques and shall recommend appropriate equipment parameters for the application.

The necessary electrical characteristics of the radio equipment will be restudied in light of the new requirement that it must transmit 60 channels, which necessitates a base bandwidth of some 250 kc.

5.4 ANTENNAS

The new specification says,

> An investigation shall be made to determine suitable antenna characteristics and arrangements for the airborne platforms and their associated ground stations for air-to-air and air-to-ground transmission.

In the light of the problems which would be encountered in multidirectional airborne transmission (many of which were presented in the Second Quarterly Report), it is planned to enlist the assistance of a group specializing in antenna design. Discussions of these problems have been held with this group preparatory to its undertaking intensive studies in the area. The word "multidirectional" as used above connotes geographical directions such as east or north. Communications in all directions will be two-way.

Problems arise because of the shadowing of antennas by portions of the aircraft, particularly during banking. Attempts to avoid shadowing by using "space diversity" (for instance by putting antennas on both the top and the bottom of the aircraft) encounter other problems. At microwave frequencies, where the wavelengths are only a few inches, even slight motions of either the sending or the receiving aircraft can result in alternate cancellation and enhancement of signals. As discussed in the Second Quarterly Report, the most straightforward solution of this cancellation problem requires four radio receivers and two radio transmitters on each aircraft for each direction of communication. Other solutions are suggested in the referenced discussion. It is expected that the antenna design group will study the whole problem and determine an optimum solution.

5.5 AIRCRAFT REPLACEMENT

The statement about aircraft replacement in the new specification reads,

> The contractor shall investigate methods of establishing an initial system and means by which switchover can be made when an operating platform is released from station and its job taken over by a replacement platform. Switchover must be accomplished with minimum interruption in the traffic being handled at the time.

The aim of this study is to determine the means for initiating communications service and for transferring radio contact from one operating airborne relay to its replacement in an airborne communication system. Specific techniques will be investigated covering both gradual and instantaneous transfer of all communications from the relay to its replacement. The transfer of communications involves both technical and procedural factors, dictated by the system features and parameters. Although the system aspects are not to be included in the present study, assumption will have to be made about the variable factors, which will provide a basis for developing the techniques and procedures involved in aircraft replacement.

During the reporting period, the previous work on system planning has been drawn upon and a number of system configurations have been established. This material is being used in developing the optimum methods for aircraft replacement. The variable factors include:

a. Network size and extent of services to be provided

b. Allowable outages (both rate of occurrence and time per outage)

c. Performance of various aircraft

d. Performance of various intrasystem communication equipment

e. Meteorological and diurnal effects

f. System control factors

Reasonable boundaries have been placed on these parameters so that only the most probable combinations are being considered. Emphasis is initially being placed, for instance, on the single-belt configuration using multi-engine, propeller aircraft in current use. The work will then be extended to cover configurations that employ jet aircraft. The double-belt network may also be studied later. Previous studies have considered such networks for spanning the continental United

States with airborne relays. Figures 9 and 10 illustrate possible single-belt and double-belt configurations respectively.

The results of the previous work in the area of system control are also being applied in this study to determine procedures that will minimize interruptions in service. It is believed that the organization and procedures provided for system control and coordination will directly affect the efficiency and reliability of the communication system. Such an organization is needed to initiate service and provide for its continuity. It would direct real-time operation, effect the required coordination, and arrange for the needed support.

To initiate and maintain service, communication ties will be required between the Airborne Communication System and weather services, users, Air Route Traffic Control Centers, and other services. A determination of these specific needs is beyond the scope of this program. However, general assumptions will be made to provide a basis for estimating the amount of coordination required and the time intervals involved in initiating service and replacing aircraft.

A draft of a report on the requirements for equipment and communication facilities in the areas of service initiation and aircraft replacement is being prepared.

5.6 FREQUENCY ALLOCATIONS

5.6.1 Introduction

Technical Requirement SCL-4313A states,

> The contractor shall study the requirements for suitable and efficient radio relay frequency allocation plans in the 4400 to 5000 mc band, including the air-to-air and air-to-ground system considerations . . . .

The activities in this area will be essentially a continuation of the work undertaken as part of the system study prior to the redirection of the program. In order to provide a basis for discussing the continuing frequency work, a review of the frequency allocation study to date is presented here.

It is apparent that any consideration of the problem beyond its most general aspects requires reference to specific system objectives and configurations. Since information of this nature has been only partially available, it was decided to study the radio frequency requirements for a variety of systems and to develop methods by which an appropriate assignment plan could be built up to fit the requirements of any system of the general type under consideration. Specific work areas are discussed below.

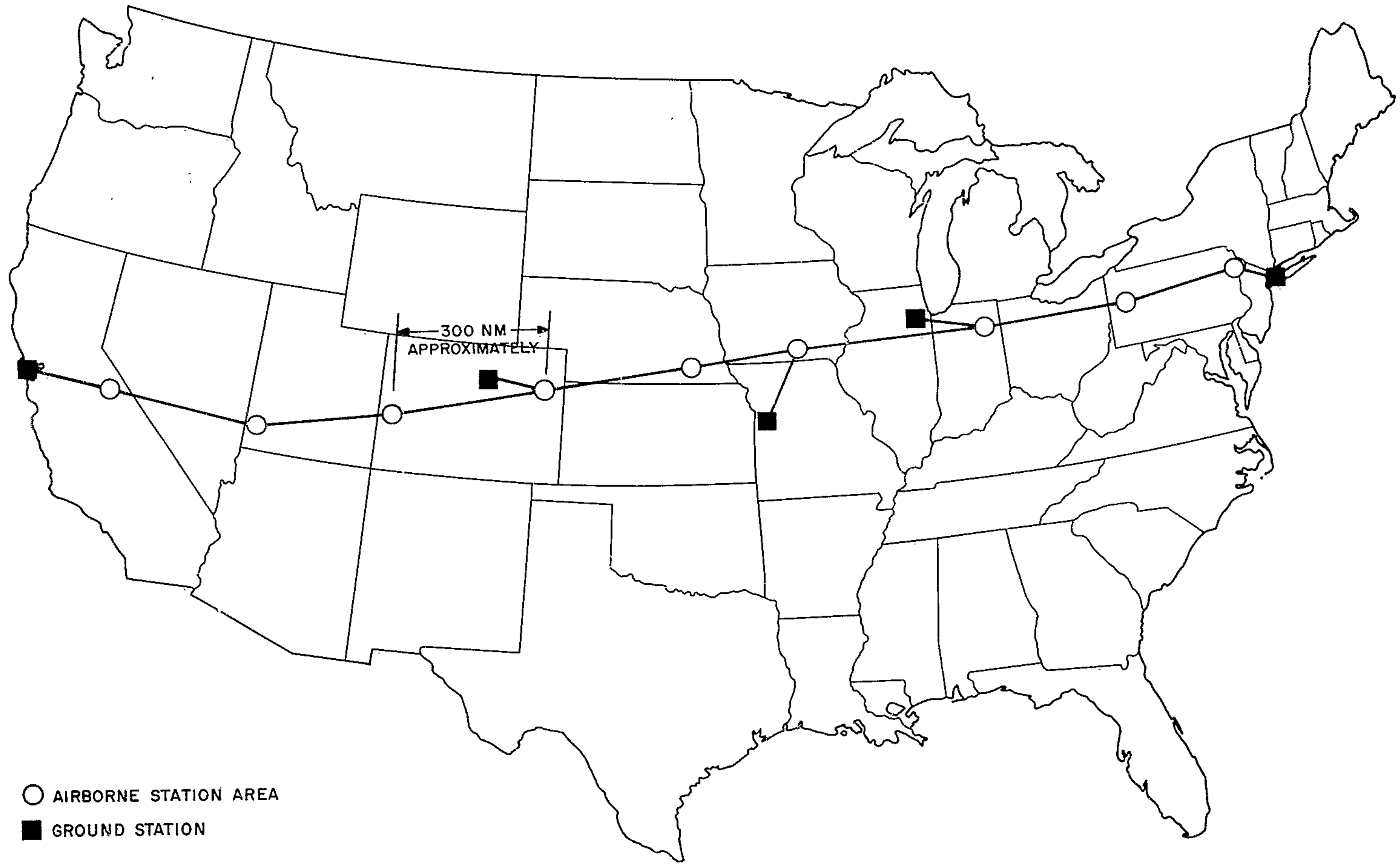


Figure 9. A Possible Single-Belt Relay Configuration

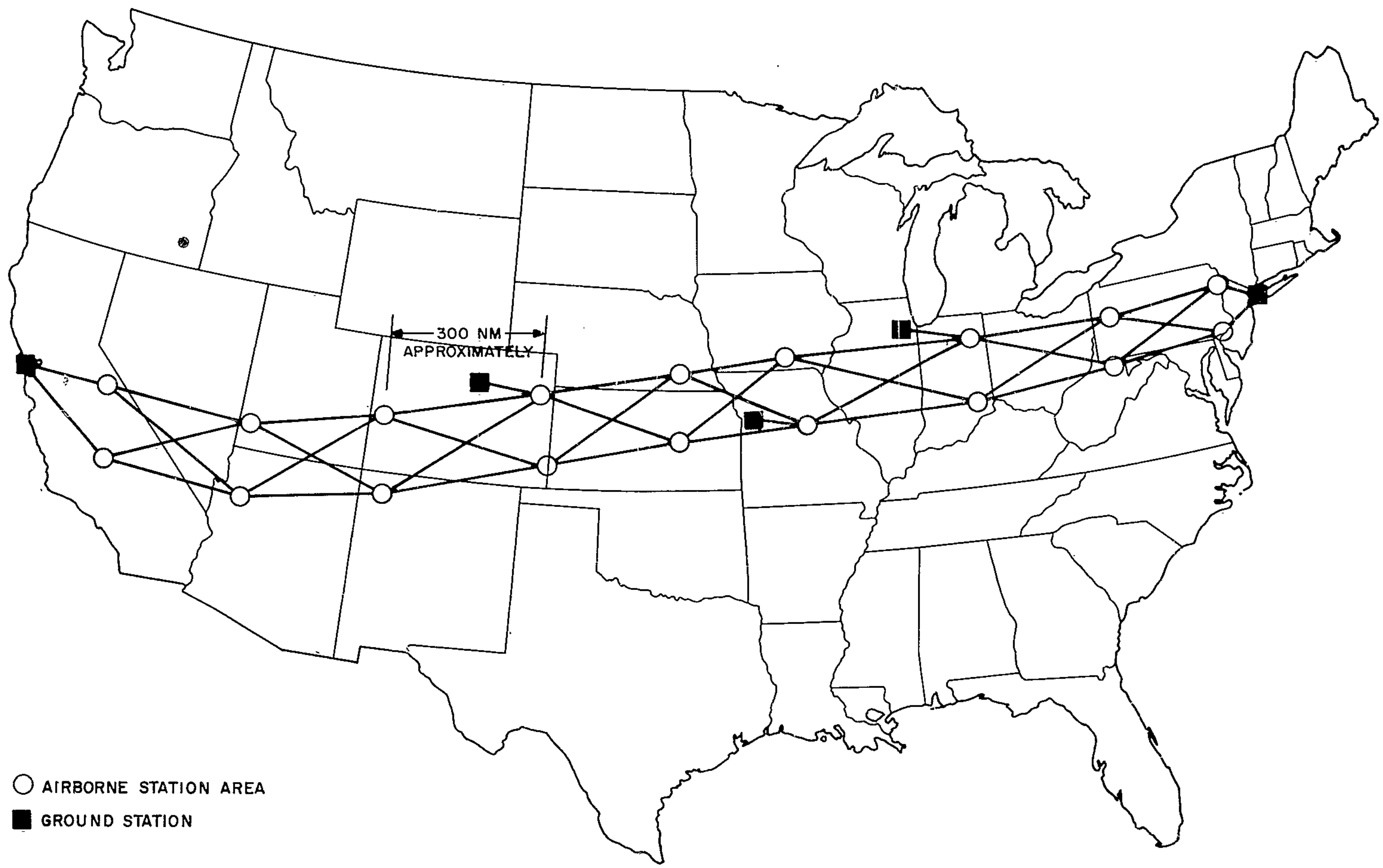


Figure 10. A Possible Double-Belt Relay Configuration

5.6.2 General Objectives

The primary general objectives in radio frequency planning are considered to be freedom from interference, flexibility, and economy of the r-f spectrum. In order to avoid interference, the total environment must be considered, not only the system itself. The degree of flexibility to be provided is a function of the over-all system objective in this area. Specifically, the frequency plans must provide for changes in routing; for route extension; and, if required, for rapid establishment of new systems. Spectrum economy calls for satisfying the first two objectives with as little spectrum usage as possible.

Since freedom from interference is a basic requirement for any plan, the primary conflict to be resolved in the design of a frequency plan for the system is the one between flexibility and economy of frequency spectrum. In general, greater flexibility is obtained only at the expense of larger frequency requirements. Hence, in the interests of frequency economy, it is desirable that the frequency plan provide only the required degree of flexibility. In short, the frequency plan must be tailored closely to the operational requirements.

5.6.3 Interference Considerations

Freedom from interference has been postulated as a primary objective in radio frequency planning. This objective is potentially difficult to achieve since conditions will exist in the Airborne Communication System that could easily cause severe interference.

Both ground and airborne stations will normally be transmitting on several system frequencies simultaneously. In the airborne station, the problem is complicated by the restricted space available, the consequent proximity of equipments, and the resulting increased likelihood of undesired coupling between equipment. A further problem in the aircraft is posed by the operation of the various electronic devices normally used for communication and navigation. At the ground station, space is not such a severe problem, although even there the equipments will probably be close enough to each other for undesired coupling unless adequate precautions are taken. The problem at the ground station will increase if a ground station is designed to communicate with more system stations than an airborne station communicates with. This would necessitate more operating frequencies and more equipment in the ground station. It can also be expected that additional equipment will be in operation at the ground station to interconnect it with the users of the system. Thus, each type of station will have ample opportunity to generate interference unless specific measures are taken to deal with the problem.

The types of interference may be categorized as follows:

a. Co-channel interference
b. Adjacent channel interference
c. Cross-modulation
d. Desensitization
e. Intermodulation
f. Spurious radiations and responses

Specific measures are indicated for avoiding each type. In general, however, avoidance of mutual interference within the system will require due attention to the areas of frequency planning; equipment design, layout, and interconnection; and operating techniques. A very desirable equipment feature is a high order of selectivity between the antenna and the first portion of the equipment, considered from the antenna end, in which interference can be generated. In all of the forms of interference, the level of interfering signal at a given receiver will be function of, among other things, the actual isolation existing between transmitters and between transmitters and receivers. In a compact environment, such as that visualized in the airborne platform, this establishes a requirement for a minimum of undesired coupling between equipment.

The increasing technology being built up in the field of interference prevention should make it possible to specify in the equipment those characteristics found necessary to avoid interference in the system. In practice, this will probably be more in the nature of a compromise, in which desired characteristics are specified, attainable characteristics are fed back from equipment designers, and the preliminary design of the frequency plan is modified accordingly.

While all reasonable steps should be taken to avoid interference involving other users, it appears that the most generally effective measures will be those that should be taken in any event to reduce the possibility of interference within the system.

5.6.4 Frequency Assignment Plans

As noted above, for the most efficient use of frequencies, the assignment plan should be designed for a specific system. Since final system characteristics have been largely unknown, plans for various systems have been investigated. Two types of plan have received primary attention to date: one with minimum flexibility, which would be designed to fit a specific network configuration; the other, one with maximum flexibility, in which frequency assignments would be dictated only by station locations. Such locations would be unrestricted. As expected, frequency requirements are relatively low for the minimum plan and quite high for the maximum plan.

For both plans, and for any frequency plan, a fundamental consideration is the minimum distance needed between a desired receiver (R_D) and a potentially interfering transmitter (T_I) on the same frequency. If the system uses omni-directional antennas, the problem is essentially one of ensuring that this distance ($R_D T_I$) exceeds the radio line-of-sight distance by an amount which will sufficiently attenuate the interfering signal. The necessary amount of attenuation will depend on the advantage of desired signal over interfering signal that must be maintained at the receiver with a specified depth of fading on the desired path. If directional antennas are used, antenna directivity may permit a significant reduction in the minimum value of $R_D T_I$; this depends on the characteristics of the specific antennas used.

For the minimum plan, frequencies are assigned to the stations in sequence. Assignments are repeated wherever the minimum separation criterion is satisfied.

For the maximum flexibility plan, an area assignment method was chosen. Area size is calculated so that stations in closest-spaced areas using the same frequency group will always be separated by at least the distance needed to avoid interference.

Some work remains to be done on the two plans discussed above, after which investigations will be made of some intermediate plans, more flexible than the minimum but less costly than the maximum. Beyond this, it is planned to study criteria and procedures to be used in selecting system frequencies.

6. CONCLUSIONS

It has been tentatively concluded that the branching of 12-channel groups from 60-channel supergroups will present no major technical difficulties.

Branching (and other types of switching) in the airborne platforms can be accomplished best on a "per mission" basis and not normally during flight.

Frequency studies to date indicate that a frequency plan providing maximum assignment flexibility is extremely costly in terms of r-f spectrum. A less flexible plan seems indicated for the expected system configurations.

7. KEY PERSONNEL

The historical sketches of the key technical personnel presently engaged in this project were presented in the First Quarterly Progress Report, dated October 15, 1962.

Appendix A

CONCLUDING DISCUSSION OF AIRBORNE CHANNEL SWITCHING

by

W. Koenig

This appendix concludes the discussion of airborne switching given in Appendix E of the Second Quarterly Report. Since this is an essential part of that discussion, it is presented here for completeness. In particular, a form of switching not included in the previous discussion will be described and evaluated.

1. ASSUMED AIRBORNE CONFIGURATION

In order to permit at least a partial evaluation of the gains that might accrue from certain airborne switching procedures, a portion of an airborne communication system was studied, as shown in Figures 11 and 12. This portion includes two airborne platforms, each connected to the other by a 12-channel radio link and capable of communicating by radio to a ground station. The platforms also communicate by radio in directions called west and east; these could represent terminal stations, but they might also represent E and W continuations of the chain of airborne relays. It will become apparent why two platforms must be included rather than just one.

2. TYPES OF CALLS

In the configuration shown in the drawing, a call might originate from the W direction and go right through to E; this type of call has been arbitrarily designated a type A call. Type B originates in W and terminates in ground station G1. Type C originates in W and terminates in G2. Actually, it will make no difference which is the origin and which the destination. Switching facilities to implement these options are described in the previously referenced Appendix E. Types D, E, and F complete the possibilities, as summarized in the table on the following page.

Type of Call	Stations Interconnected	Stations Excluded
A	W, E	G1, G2
B	W, G1	G2, E
C	W, G2	G1, E
D	E, G2	G1, W
E	E, G1	G2, W
F	G1, G2	W, E

The procedure that formed the basis of the subsequent discussion was to assume that at some initial time all channels are idle; then calls of the six types occur in a random sequence. The number of calls that could be successfully completed before the first block occurred was counted in each trial. In order to assure randomness, tables of random digits were used, assigning digits 1 to 6 to call types A to F, respectively. Each experiment was performed a sufficient number of times (usually 10) to ensure that the average result would not be changed radically by subsequent trials.

In some of the experiments it was assumed that no calls were released during the period under scrutiny. In others, the random digits 7 and 8, when they occurred, were taken to signal the release of calls, in the sequence in which they originated; this corresponds to the situation, which might be an emergency, in which calls come in at a faster rate than they are released. In other experiments the digits 7, 8, 9, and 0 were taken as release signals; this corresponds to four calls ending for every six originating.

These experiments were conducted for each of three assumptions as to switching operations performed in the airborne platforms, as described in subsequent paragraphs.

3. RE-USE OF CHANNELS

In Appendix E of the Second Quarterly Report, a switching option was described that would permit the re-use of an unused portion of each channel. In the present configuration, this can occur for only two of the six types of calls: if a type B call has been received, a D call can be put on the unused portion of the same channel (and of course vice-versa), provided that an airborne operator correctly actuates certain switches. (These particular switches, however, do not permit connecting a portion of one channel to a portion of another channel. This possibility will be explored in the next section.) Therefore, a type A call on a particular channel effectively ties up all of that channel. The same is true of types C, E, and F. For instance, in Figure 11, which illustrates a typical sequence of calls, with

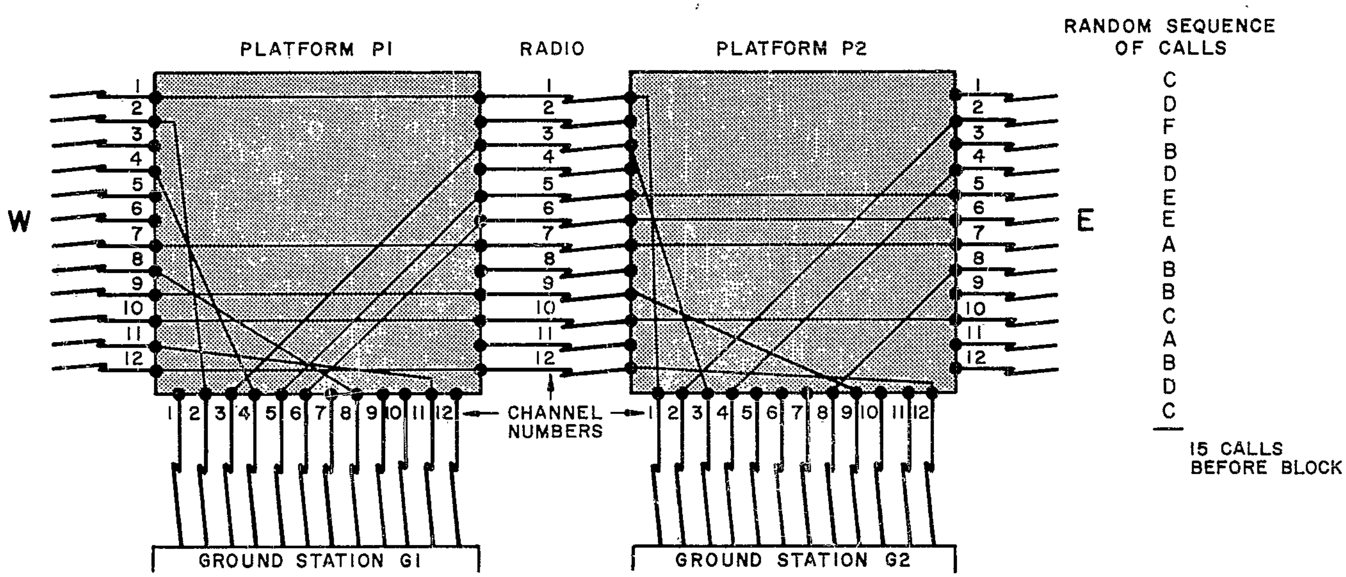


Figure 11. Airborne Channel Branching — Typical Result Assuming Re-use of Channels, No Release

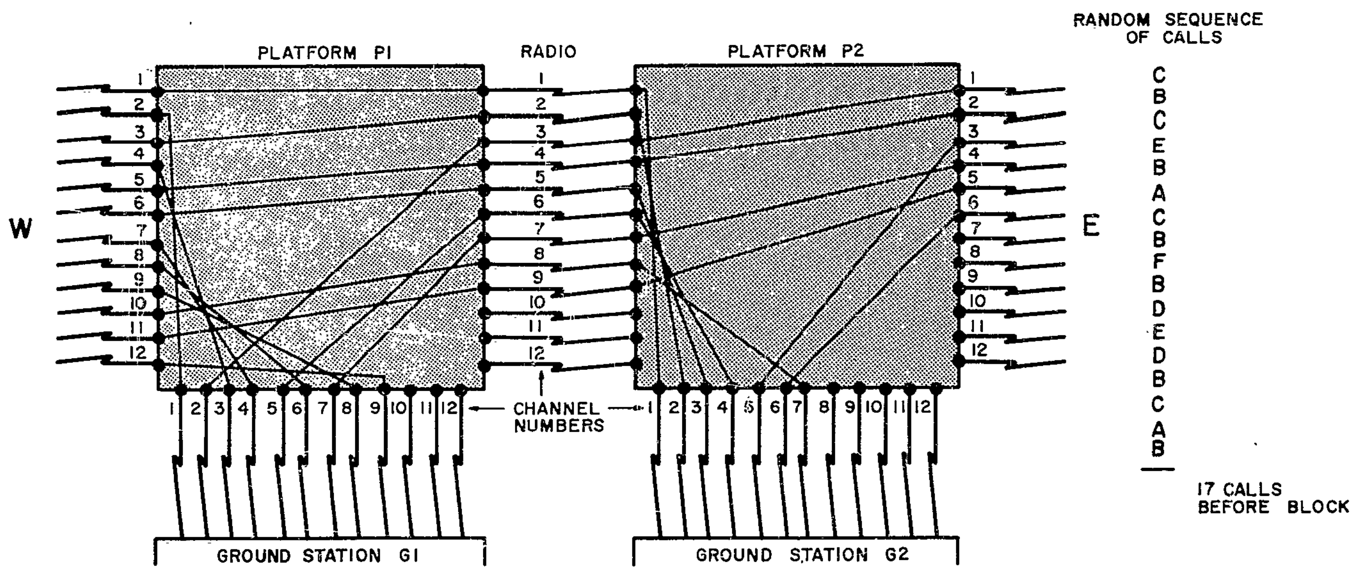


Figure 12. Airborne Channel Branching — Typical Result Assuming Patching of Channels, No Release

the lines inside the squares representing the corresponding switch connections, note that the first call was type C, which connects W and G2. This would seem to leave channel 1 open for calls to or from E; but both other appearances of channel 1 in P2 are busy. Therefore, the E portion of channel 1 cannot be used in P2. The same is true for channel 1 coming in from G1 in P1. In contrast, the second call is type D, which interconnects G2 and E via channel 2. This makes channel 2 of the radio link between P2 and P1 useless, but permits the use of channel 2 in P1 to interconnect W and G1, which is a type B call.

The particular sequence shown in Figure 11 resulted in a better than average score since 15 calls were accommodated on 12 channels, an effective gain of 25 per cent. The average of all scores was about 11 per cent above the total of 12 calls that could be handled with 12 channels if every call made every channel busy throughout its length — that is, if no switching were done in the airborne platforms. Note that when this run was finished, one more call, a type D, could have been accommodated had it occurred in the random sequence. A summary of all the results will be discussed in paragraph 6.

4. CHANNEL PATCHING

One possibility that was not considered before is the provision, in the airborne platform, of the equivalent of a patchboard by which any channel could be patched to any other channel. This would be the most flexible switching arrangement that could be devised. The experiments described in the previous paragraph were repeated, therefore, on the assumption that an operator would patch together portions of channels as needed to interconnect the originating and terminating stations. Calls were again assumed to be coming in random sequence, the operator always patching to the lowest available channel. This is the most orderly procedure, but any other patching rule would have given the same end result. Some kind of signalling system would be required in practice to keep the successive operators apprised of the origin and destination of each call; an order wire would be the simplest to envision, although it would be slow. As before, various release rates were postulated, governed by the random-digit sequence. This operating procedure, of course, includes the re-use possibility (paragraph 3) but goes further in flexibility, and therefore will accommodate more calls on a given number of channels. A typical trial is illustrated in Figure 12. This trial resulted in 17 calls on 12 channels — a gain of 42 per cent, which is close to the average of all trials. Note that, at the finish, several more calls could have been handled had they occurred, divided among types D, E, and F. In this trial, W became loaded first; in other trials, the radio link or one of the other stations became saturated.

Table 2

AIRBORNE CHANNEL BRANCHING — SUMMARY OF ALL TRIALS

	12 Channels			24 Channels		
Condition	No. of Completed Calls	Increase Over No Switching (%)	Increase Over No Release (%)	No. of Completed Calls	Increase Over No Switching (%)	Increase Over No Release (%)
No Release and						
(1) No Switching	12.0	—	—	24.0	—	—
(2) Re-use Channel	13.3	11	—	27.3	14	—
(3) Patch Channel	16.9	40	—	36.6	52	—
1/3 Release and						
(4) No Switching	19.2	—	60*	34.5	—	44*
(5) Re-use Channel	21.0	9	57†	44.2	28	62†
(6) Patch Channel	23.1	20	37‡	49.6	44	36‡
2/3 Release and						
(7) No Switching	27.2	—	127#			
(8) Re-use Channel	31.2	15	134**			
(9) Patch Channel						

*Condition (4) compared with condition (1).
†Condition (5) compared with condition (2).
‡Condition (6) compared with condition (3).
#Condition (7) compared with condition (1).
**Condition (8) compared with condition (2).

5. INCREASING THE NUMBER OF CHANNELS

The experiments described in paragraphs 3 and 4 were repeated on the assumption that 24 channels were available instead of 12. As expected, the number of calls that could be handled increased, in most cases, by a ratio of slightly more than 2 to 1.

6. SUMMARY OF RESULTS

The results of all the runs are summarized in Table 2. The blanks represent conditions not tested because it was judged that these particular tests were by their nature too time-consuming and would not contribute much to the over-all picture.

Note that re-use of channels gave gains ranging from 9 per cent to 28 per cent. Patching gave gains ranging from 20 per cent to 52 per cent. The release of calls, even at a 1-to-3 ratio, greatly increased the traffic-handling capacity. All of these results appear quite reasonable, and they are sufficiently consistent so that it was felt that further work on this particular configuration would not be justified.

7. DISCUSSION

The conditions labeled "No switching" require no personnel charged with this responsibility in the airborne relays. The other conditions all require trained personnel who probably would have to spend full time on the switching or patching of calls. While the trunk efficiency would be thereby increased, this could lead to mixups such as superposing or breaking busy channels, and there would be other disadvantages as discussed in the previous report.

The matter of signalling is also of some concern. The signalling system would have to indicate, for instance, that channel 3 may be used up to but not beyond G2. This is not impossible, of course, but may require some development.

It is believed that, when all factors are considered, airborne switching under the conditions assumed in these experiments is simply not worthwhile. It would be much better to provide enough channels to handle the expected traffic without switching.

This does not necessarily mean that airborne switching facilities should not be provided at all; it simply means that switching should not normally be done during a given flight. A relay that will serve no branch point certainly should be patched straight through. And if certain channels are to be assigned on a "hot-line" basis to certain users, these patches or switches should be made. But these are "per mission" types of options that could be accomplished before the aircraft leaves the ground. Thereafter, the channels might be left undisturbed, except possibly when some drastic rearrangement must be made because of an emergency.

Unclassified

AD______________ Accession No.__________

Bell Telephone Laboratories, Inc., Whippany, N. J. AIRBORNE COMMUNICATION SYSTEM: MARCOM RELAY, Report No. 3. Third Quarterly Progress Report, 15 Dec 62 – 15 March 63, dated April 15, 1963; 54 pp., incl. illus., tables, appendix. United States Army Signal Supply Agency Contract DA-36-039-sc-89250.

The Third Quarterly Airborne Communication System Report outlines the redirected study, the purpose of which is to gather and analyze information on air-to-air and ground-to-air microwave propagation and transmission. It also describes the plans for a Test

(over)

Abstract Card

1. Communications – Basic Plan for Airborne Communications
2. Microwave Propagation
3. Propagation

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Abstract Card

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2. Microwave Propagation
3. Propagation

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